ASTM ISP Proposal
DRAFT 1
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Effect of Moisture on the Flammability and Ignitability of Oils in Oxygen-Containing Environs

Comments:

The following draft proposal is being considered by ASTM Committee G-4 for inclusion in its Industry-Sponsored Programs series. A timetable has not been adopted but a Task Force is evaluating and modifying the contents. The proposal may be abandoned or modified extensively. Outside suggestions and comments are welcome. Forward any comments to werleybl@apci.com.

Background:

A CGA Task Force (Docket 96-86) has surveyed the cleanliness needs of systems that contain oxygen mixtures and have recommended experimentation to resolve some issues. They have found that:

1. Incidents have occurred in contaminated systems at oxygen/nitrogen concentrations as low as 3.5% (at elevated pressures and temperatures), and yet many common air compressors operate at similar pressures and elevated temperatures apparently with very low rates of incidents. In these former cases, the oxygen-containing mixtures were from cryogenic production, which are typically bone dry, whereas ordinary air compressors tend to have much higher moisture contents. The CGA Task Force has questioned whether the higher levels moisture in the latter case account for the low rate of incidents.

2. The solubility of oxygen in oils increases with pressure and some predictions place the amount that can be dissolved at a level (perhaps 5-10 mol% oxygen at cylinder pressures) that might render the mixture much more flammable than otherwise expected and perhaps even liquid-phase flammable (or explosive). Some incidents may support this prospect.

This leads to secondary questions such as:

-Might moisture thwart ignition of contaminants?
-Might moisture thwart the capacity of oils for oxygen?

-Are there threshold-pressures at which oils with dissolved oxygen become particularly hazardous?
-Does the absorption period of oxygen into oils explain why some incidents do not occur for long periods of time.

The answers to these questions may have a significant impact on industrial cleanliness practices, because many "wet" systems (air compressors, membrane and PSA oxygen systems) may require less scrupulous cleaning than cryogenic systems, if the moisture is indeed protective. This can impact the cost equation of producing and operating these plants. In addition, if there are pressure thresholds that obtain for oil hazards in cryogenically produced oxygen, these data may mitigate the need for scrupulous cleanliness in the case of low pressure oxygen systems (cryogenic or not). Finally, they may provide a new safety variable, moisture, that could be designed into certain systems (specifically systems using cryogenically produced oxygen) to control ignition (e.g. moisture is known to reduce static electricity formation [charge separation] in many cases, therefore, controlling moisture above a level may reduce the need for extreme cleanliness). These data would also be used to consider and investigate oxygen incidents (e. g. might oxygen dissolve into oil slowly and explain why so many incidents in oxygen occur so late in the hardware life cycle, or might moisture oxidizing with metals dry the gas and lead to similar late cycle ignition as charge separation becomes more likely).

Proposal

Figure 1 exhibits an apparatus that can explore several issues of interest. It includes two small vessels connected by a large bore valve.

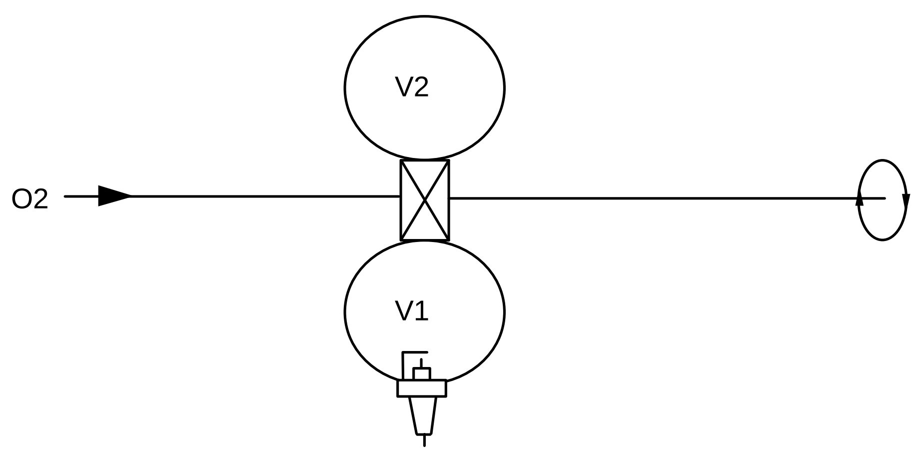

FIG. 1—*Apparatus.*

Two small (perhaps <1 in^3), inexpensive vessels, V1 and V2 are isolated by a remotely operated valve between them. The axis of the valve supports the vessels and allow them to be rotated. Vessel V1 can be filled with a candidate oil. It contains an automotive spark plug at its bottom in the position as viewed in the figure. Vessel V2 can be filled with oxygen. Separating the vessels is a ball or plug valve. The apparatus is considered sacrificial and therefore made of inexpensive components (such as spherical ARC vessels?). The following experiments can be conducted.

Solubility and rate of dissolution.

Vessel 1 may be filled with a candidate oil (including the bore of the isolating valve, V1) and the isolating valve, V1, closed. Then vessel, V2, may be slowly pressurized with oxygen to a selected level (so as to preclude adiabatic compression of any small amount of exposed oil).

Valve V1 is then opened. Since the valve bore and vessel V2 are full of oil, there is no volume change and no adiabatic compression event. The pressure of vessel, V2, is observed over time to determine the dissolution of oxygen into the oil. If the rate is very low, the vessels may be slowly rotated to expose more oil surface area and to mix them. The relative volumes of the vessels is measured by equilibrating a pressure of gas in V2 with an empty V1 and observance of the subsequent pressure drop.

Sensitivity of oxygen-bearing oil to fluid motion

By rotating the vessels, charge separation might be anticipated, and ignition may be possible. Therefore some oils would be rotated to induce a low flow rate and any ignition event would be very significant. In this phase, the dryness of both the oxygen and oil would be varied. Drying techniques for oils must be investigated. Could they be mixed with or flowed through a hygroscopic agent and simply drained? This is crucial because oils exposed to bone-dry oxygen for extended periods might be stripped of even traces of moisture and might become highly insulating (which is conducive to charge separation).

Reactivity of oil/oxygen/water mixtures

When saturated oxygen/oil mixtures are prepared and validated, and assuming spontaneous ignitions have not been observed, then ignition testing would be performed on pure components and mixtures containing varying amounts of oxygen and moisture. In this scenario, the saturated mixture would be prepared and then the apparatus rotated so that the spark plug is in the correct position (typically at the bottom, so that the spark gap is submerged) and a series of sparks would be caused, perhaps rotating the vessel between sparks to ensure fresh saturated oil is between the electrodes. In the worst cases, ignition should be obvious: heat, flame, coking of oils, perhaps rupture of vessel. However, if ignition is not obvious, it will be necessary to validate that the sparking is occurring, which would mean the installation of a window so that the gap can be observed.

Commentary/Suggestions

Ignition System

An internal combustion engine (automotive-style) ignition system is suggested because much technology has gone into their development and they are proven and well characterized. In addition they are inexpensive.

Any of a series of spark plugs is workable, however, to improve heat transfer and minimize breakdown voltage under liquid oil at high pressure, the electrodes should be filed to points (and the gap may have to be small (0.010-0.050-in.). This will be no problem because "wear" is not at issue in this test program. Thousands of arcs will be drawn instead of the billions+ of engine use (so electron beam erosion and high-temperature corrosion will be nil). I recommend a "hot rod" coil known as a "SuperCoil" manufactured by Echlin and sold also by Accel. This coil is capable of >100 KV potential at about twice the spark energy (about 50 mJ) of standard automotive coils (probably for <$100). High performance automotive wiring is also recommended.

To activate the sparks, I suggest using a capacitor discharge. Simply charge a capacitor to a few hundred volts and then connect it via a simple switch to the coil's primary. It is typical to saturate the coil with low (1 or 0.1 microfarad capacitors at two or three-hundred volts) This provides a fast-rise-time, high-peak-power arc that should be preferred for this use. In addition, ignoring losses (which might be substantial,) one can approximate the ignition energy as the energy on the capacitor ($CV^2/2$).